Computational Archaeology

N. Bordes[1], B. Pailthorpe[1], J. Hall[2], T. Loy[2], M. Williams[3], S. Ulm[3], X. Zhou[4], R. Fletcher[5]
[1]School of Physical Sciences [2]School of Archaeology, [3]Aboriginal and Torres Strait Islands Studies Unit, [4]School of Information Technology and Electrical Engineering, The University of Queensland, QLD 4072, Australia
[5]School of Archaeology, The University of Sydney, NSW 2006, Australia
nb@maths.uq.edu.au

Abstract

Innovations in High Performance Computing (HPC) and networking technologies are enabling qualitative improvements in collaborations. Panoramic computer displays and the Access Grid are prime examples that have gained traction in scientific research. Here we describe our innovations: a compact high-resolution scalable desktop display; and an all Linux Access Grid, which natively supports computer graphics and visualization. We present examples from collaborative projects initiated between archaeologists and scientists, and HPC researchers.

1. Introduction

The physical sciences have benefited from advances in computing software and hardware for the last two decades. However the adoption of high performance computing (HPC) in the social sciences and humanities has evolved at a slower pace. In more numerically oriented subjects, such as economics, there are lower barriers to entry in adopting HPC techniques. In other cases the hurdles may appear more daunting. Thus visualization and collaboration technologies, such as the Access Grid, are more likely to be of immediate use in scholarly disciplines. In this paper we present examples of collaborative, cross-disciplinary research projects in which archaeologists and social scientists work with HPC researchers.

2. Imaging processing and visualization using high-resolution displays in archaeology

The city of Angkor in Cambodia houses one of the world's largest religious monuments with spectacular stone temples [1]. Angkor was the capital of the Khmer Empire between 800 and 1400 AD. It was sacked and subsequently abandoned in the mid-15th century and "lost" until a French explorer, Henri Mouhot, "re-discovered" it in 1860. Restoration plans started at the beginning of the 20th century were interrupted by the civil war of l970-1975 and during the Khmer regime. As a consequence the area lying north of Angkor is heavily mined and direct examination of the site is dangerous. This situation inhibited traditional archaeological discovery and excavation techniques. Thus Airborne Synthetic Aperture Radar (AIRSAR) imagery now is an essential tool for archaeologists to study this area [2, 3, 4]. AIRSAR uses three wavelengths, L-band (23 cm), C-band (6 cm) and X-band (3cm) to image a landscape. The longer wavelengths can penetrate through the overlying dense forest canopy and, in extremely dry areas, through thin sand cover. This imaging technique offered a new view of Angkor and its surroundings, augmenting information gathered using traditional techniques. It led to the discovery of circular pre-Angkorean mounds and undocumented temples [5, 6]. In order to study the extent of Angkor, image processing techniques (edge detection) were used to detect human-made features. Such features are usually geometric as humans generally pattern space in a straight or circular fashion. We originally used AVS to display, analyze and visualize the radar data in 3D. The study showed that a network of roads was present to the north of the complex of temples, indicating that Angkor was more extensive than previously thought. Such imaging naturally calls for higher capacity and higher resolution displays.

2.1. High-resolution display

One of the bottlenecks for analyzing large data and image files comes at the display level: desktop displays, whether cathode ray tubes (CRT) or liquid crystal displays (LCD), are often restricted to about 1 million pixels (1280 x 1024). Tiling together projected images offers one simple way to achieve a seamless large image [7-14] Uniformity of brightness and color is not easy to achieve because of the manufacturing variability of commodity projector components (filters lamps, optics, etc). This leads to differences in illumination and colors, and degrades the overall image quality. A new tiled projection display system, developed by Pailthorpe and Bordes in collaboration with JVC [15,16] solves many of these problems by using a common light source and common dichroic filters, resulting in superior performance. The red, green and blue light components are guided by optical fibers onto the D-ILA chips of the JVC projectors. The 3 x 1 projector array yields a final image of 3840 x

1024 pixels with physical dimensions of 128 cm x 32 cm, and preserves the usual desktop resolution of 72 dpi. Each projected image tile is 21" diagonal, as illustrated in Figure 1. The compact, essentially desktop, display eliminates the need for special-purpose rooms or architectural modifications that tend to add significantly to project costs. The system is driven by a PC graphics cluster running Linux so that, all up, it has a low cost (< A$100,000). This substantially lower cost is a non-trivial issue, since there tends to be a small funding available for project in the humanities and social sciences.

Figure 1: Square Kilometer Array radio telescope showing uniformity of gray levels.

Our new compact, scalable, high-resolution display, developed in Sydney VisLab and SDSC, allows the seamless viewing of multi mega-pixels images such as AIRSAR images at one time without being limited by the available surface area of common desktop displays (figures 2-3). The radar images are shown on the desktop tiled display. By contrast with a PowerWall, this display is desktop scale, being approximately 1m (~ 3 ft.) wide. The display was used to examine details within the perspective of the panoramic AIRSAR image. Such approaches augment traditional research methodologies in archaeology and guide future fieldwork and excavations.

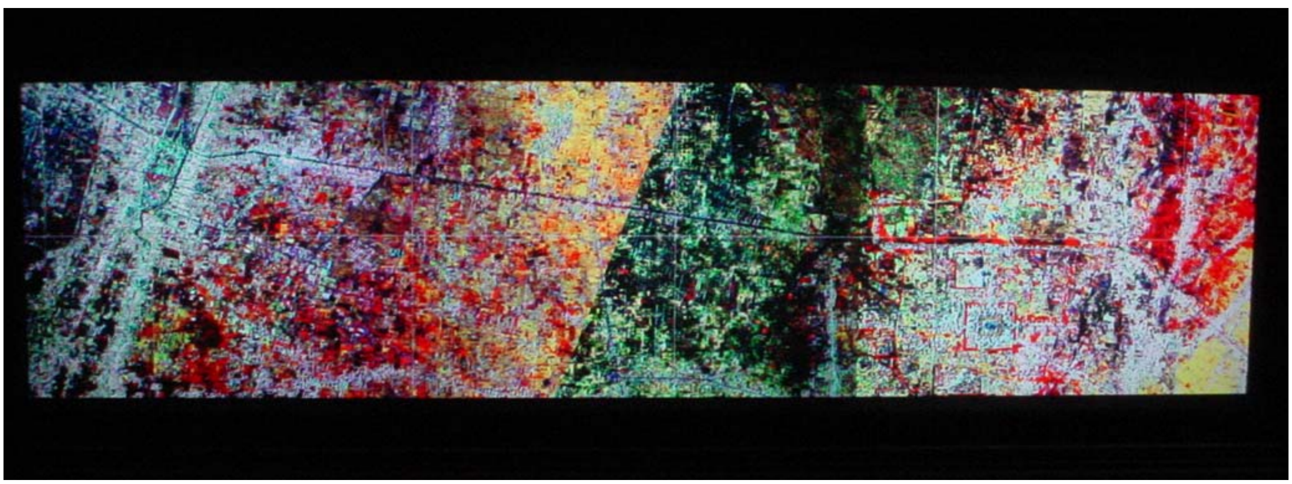

Figure 2. AIRSAR image of the central area Angkor, displayed on the black screen.

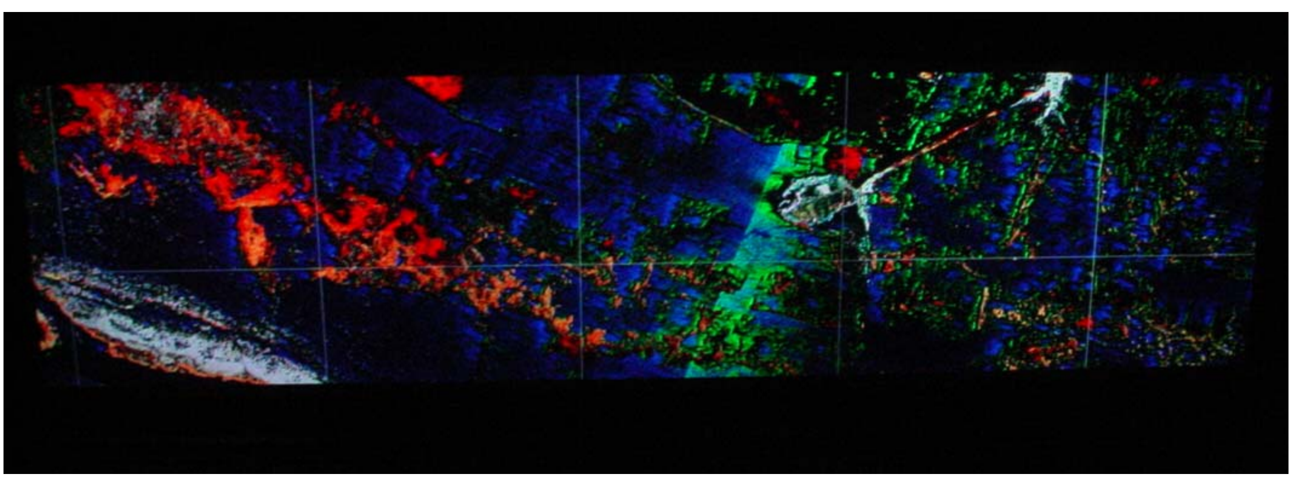

Figure 3: AIRSAR image of the great lake south of Angkor.

2.2. All-Linux Access Grid and PowerWall display

We were responsible for introducing the Access Grid to Australia in 2001. In order to do this, we re-built the system as an all-Linux implementation. That allowed the three PC stacks to operate natively as a graphics cluster. Thus the Access Grid also functioned as a low-cost PowerWall display, and graphics applications could be shared amongst sites, as well as PowerPoint slideshows, etc.

Argonne National Laboratory (ANL) originally developed the concept of the Access Grid (AG), a collaborative environment that allows group-to-group working over the Internet using multicast [17, 18]. These AG nodes provide rich portals to grid resources and are more than just video conferencing facilities. The Access Grid was recognized as having great potential for Australian researchers since it breaks down the "tyranny of distance" between Australia and the rest of the world. The motivation to alter the ANL design in 2001 arose from our need to more efficiently utilize the then available bandwidth in Australia and the Asia-Pacific, and to reduce costs. Starting from the ANL concept, we have modified the design to an all-Linux implementation [19], rather than a mixture of Linux and Microsoft Windows, as used elsewhere. The single operating system reduces system complexity and costs, and enhances AG capabilities, to include computing and advanced graphics functions. Technical details have been presented [19] – essentially, these include to support for: graphics clustering using Chromium; tiled display mode with OpenDX, OpenPerformer and OpenInventor; high resolution video; and new media streams. Figure 4 illustrates the PowerWall mode of operation of the all-Linux Access Grid in studying AIRSAR images of archaeological sites.

Figure 5 illustrates the cluster display design of our Access Grid This contrasts with a standard AG display - of the three projected areas, two are driven via AGP card and one via PCI card, while a second PCI card supplies the control monitor.

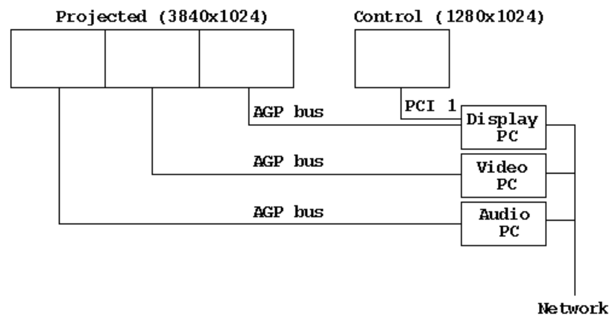

Figure 5: All-Linux Access Grid with clustered display. Of the three projected areas, all are supplied from the AGP card of each individual machine - *i.e.* all three are display machines.

The new AG design facilitates muli-user and group collaborations via Access Grid, now augmented by panoramic graphics. Individual users now are not limited by having to "window around" the large AIRSAR images, as they would on a standard desktop display.

3. Historical illustrations using visualization

The Great Cities project led by Fletcher at the University

Figure 4: All-Linux Access Grid with clustered display. Of the three projected areas, all are supplied from the AGP card of each individual machine - *i.e.* all three are display machines.

of Sydney rises a few interesting questions on the limits of settlement growth that might have repercussions to 21st century city dwellers [20]. As part of this study, we created visualizations showing graphically the growth and decline of the city Baghdad from 750 AD until 1,400 AD. The animations combined Geographical Information Systems (GIS) data and city boundary data obtained from ancient texts [21]. The white regions on figure 5 indicate the size of Baghdad for a given year, the red the area of growth. Areas showing a decrease were displayed in blue. The animation runs at 10 years per second.

This example shows both the power and the dangers of visualization. This animation uses interpolation between the years for which the shape of the city is grown: the computer creates the missing frames by interpolating between two key frames. In addition a certain growth mode has been chosen (linear and normal to the original boundary curvature), which may not reflect what really happened. Knowing the conditions and hypothesis, this animation is still a compelling presentation of how the city grew. This work now has been expanded to include other ancient cities as well as empires and has led to the Time Map project [22].

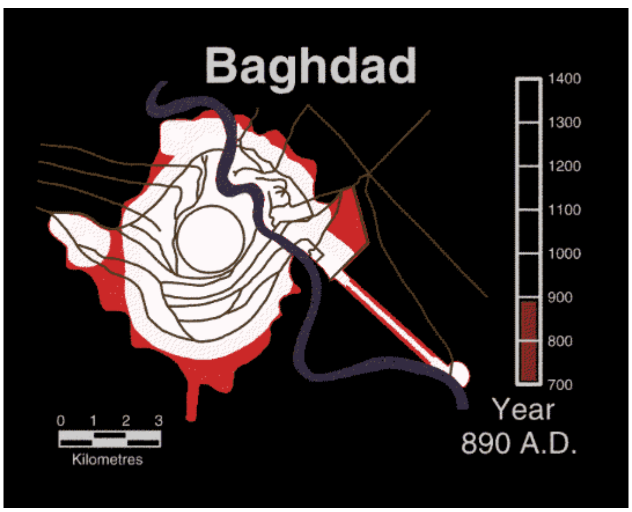

Figure 5. Frame from the growth and decline of Baghdad animation.

4. 3D archaeology

Archaeologists remove material from the site: dirt, organic materials, artifacts, etc. It is basically a destructive process. Hence special care is taken to document every find. Although archaeologists still excavate with hand tools, like their 19th century predecessors, instruments such as digital survey tools (Total Station), GIS and, digital cameras are bringing a wide range of digital technologies to traditional field archaeology, generating a large amount of data [23]. Data with coordinates are processed in GIS programs, while others such as videos and images are stored in a searchable database. Although useful, such data do not allow for a physical representation of the archaeological dig.

Stratigraphy is essential to understand how and why an artifact is found where it is. In undisturbed sites, this is simple; however in catchment areas or seismically active places, the artifact might have been moved by water or earthquakes from its original position to the one where it is found or it might have moved up to a "younger" layer.

Stratigraphy is crucial to this work and elaborate schemes have been devised to record vertical and horizontal relationships [24]. Techniques such as photogrammetry are difficult to use and are image based. Cameras need to positioned carefully and measurements need to be taken several times during the season to record the progression of the work. However innovative and useful these new tools may be, none permit a visual physical representation of the archaeological site – a 'virtual site' through which archaeologists could study the site almost as it was during excavation and even carry out subsequent quantitative measurement and analysis.

A core aim of a new project currently under development at the University of Queensland is to establish a visualization tool with basic analytical techniques that enables an ensemble of archaeological artifacts to be analysed and understood within the dig matrix. We are currently collating data from the TARDIS site an artificial multi-component site containing 'seeded' artifacts and cultural features in specifically defined and recorded associations that represent behavioral scenarios from prehistoric cultures worldwide [25]. Using these data, a prototype is being developed with OpenDX to display the artifacts in 3D within their associated strata and to allow measurements to be made. In order to integrate the site within a larger region, we will use XML (eXtensible Markup Language) to move the data between the visualization software and GIS applications, allowing the researcher to move from one scale to the next and also to perform statistical analysis (using Matlab for instance). Such a tool will recreate the site as it was during the archaeological season and provide a reference for subsequent work.

5. Cultural Database

This project aims to create a repository of knowledge for Indigenous Australian communities. The information is diverse: some of it is relevant to archaeological sites and artifacts (pictures, coordinates, GIS files) other to cultural data such as geographical areas of importance, sacred stories and information about the communities themselves. The goal of this project is to create a web-implemented application, which will allow a user to do text-based queries and will return a list, in order of most relevant to least relevant, and classified by media types. One of the requirements and challenges in this project relates to access privileges. In addition to who can access the database, not everybody with access privileges can view the available material. For instance some Aboriginal stories are secret and cannot be revealed to non-initiated persons. Similar restrictions are also gender-related: men cannot have access to women's secrets and vice-versa. We have not found a satisfactory solution to this requirement.

6. Education

The collaboration between the sciences and the humanities can only prosper and be successful if some of the knowledge is passed on to students. A new scientific data visualization course aimed at archaeologists and social scientists will be offered at the University of Queensland in 2005. This course will propose hands-on experience to arts and social science students. Topics include scalar data visualization, GIS, basic statistics, basic image processing. The students will use existing software applications and apply their knowledge to undertake a small project.

7. Comments

In our experience collaboration between two different disciplines starts because there is a mutual interest between the individuals and also a realistic understanding of what computer technology can or cannot deliver. The human collaboration comes first – then the Access Grid and panoramic displays can enhance the collaborations. Projects in the humanities have similar IT requirements to those encountered in the physical sciences: databases, visualization, collaborations, etc. However the key points in such cross-disciplinary projects are to maintain the collaboration beyond the proof-of-concept phase, to train researchers on how to use the technology, and also to expose humanities students to new technologies during their studies. Because funding for archaeology is usually modest, there is also a need to develop solutions that are inexpensive and can be deployed on the field. These constraints yield their own technical challenges. Archaeologists and social scientists (as well as researchers in the physical sciences) expect new technologies to be robust. Our initial historical animations (illustrated by Figure 5) that were generated in our lab eventually facilitated the Time Map project in its own right.

8. Acknowledgements

This research was supported by the Australian Research Council. We gratefully acknowledge the help of Chris Willing and Timothy Hackett. I. Tapley from CSIRO facilitated access to the AIRSAR images. B. Simons rendered the Baghdad images.

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